Preliminary Results Towards Building a Highly Granular QoS Controller

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Abstract. In this paper, we describe a function to be used in a video distribution tool with user-driven QoS control. Controller acts based on this function whose dimensions are bit rate, QoS level and quality. Our results show an alternative for reducing the function construction cost.

1 Introduction

QoS adaptation mechanisms are often based on control systems. The controller initiates some corrective action in order to bring the observed parameters back to the acceptable ranges (e.g., packet loss rate between 5 and 10%), usually changing the multimedia stream bit rate by degrading one QoS parameter from the application layer (e.g., reducing video frame rate, or resolution or the quantization factor value of the encoder, for live data applications). Thus, quality is dealt as an one-dimensional phenomenon, neglecting that under user' perspective, changes in one dimension can influence the perception of the others. This simplification is mainly due to the lack of a compressed video quality assessment in terms of dynamically changeable QoS parameters of the application layer. We believe that the construction of controllers supporting highly granular quality imposes a mapping bit rate↔QoS level↔quality, where a QoS level is a combination of values of several application layer QoS parameters and quality is quantified by an objective measure. The advantage of highly granular quality controllers is to get a smooth QoS adaptation and the best quality according to end-users when shaping the multimedia stream to the available bandwidth.

2 Quantifying Quality

In [1], we describe a general framework for QoS adaptation. The framework is based on using a table containing *QoS levels*. A *QoS level* L is a n-tuple $< \rho_1, \rho_2, ..., \rho_n >$ representing a combination of values of the n QoS parameters from the application layer. Associated to each QoS level, there is the bit rate (B) needed for supporting it and the *quality degree* ($Q\hat{o}S$), a metric used to quantify the quality of QoS levels in agreement with user's perception. Therefore, each entry of the table is a $(n+2)$-tuple $< \rho_1, \rho_2, ..., \rho_n, Q\hat{o}S, B >$. The value of $Q\hat{o}S$ is obtained using the quality degree function $\mathcal{Q}o\mathcal{S} : P \mapsto [0, 1]$

$(P = P_{\rho_1} \times P_{\rho_2} \times ... \times P_{\rho_n})$. For the QoS level $L_j =< \rho_{1_j}, \rho_{2_j}, ..., \rho_{n_j} >$, $Q\hat{o}S_j = \mathcal{Q}o\mathcal{S}(\rho_{1_j}, \rho_{2_j}, ..., \rho_{n_j})$. By $\mathcal{Q}o\mathcal{S}$, QoS adaptation mechanisms can select the (theoretically) best combination of application QoS parameters values for a given network bit rate. The definition of a choice criterion is important since different L's can have similar requirements of bit rate representing completely distinct qualities.

A key step of our framework is the QoS levels quality assessment by subjective tests, that might be very time-consuming, depending on the cardinality of P ($|P|$), even after discarding many QoS levels. Note that the more P_{ρ_i} sets considered, the less user' perception to QoS level change (QoS adaptation) during the multimedia application session. For example, let just three QoS parameters: video frame rate, whose domain goes from 10 fps to 30 fps, pixel depth (number of colors), with three values (8, 16, and 24 bits/pixel) and the DC accuracy (8, 9, 10 and 11 bits/pixel). In this case, we would have to perform $k \times 252$ quality evaluations, since $|P| = 21 \times 3 \times 4 = 252$. k is the number of tests for objective tests or human subjects for subjective tests. In this paper, we propose an approach for reducing the complexity of $\mathcal{Q}o\mathcal{S}$ construction from $P_{\rho_1} \times P_{\rho_2} \times ... \times P_{\rho_n}$ to $P_{\rho_1} + P_{\rho_2} + ... + P_{\rho_n}$ without loosing accuracy.

3 Reducing Evaluations

Due to the cost of quantifying the quality considering as many QoS parameters as possible, we have developed an alternative approach based on using *utility functions* [2] for each QoS parameter. A utility function is a bidimensional function which associates a utility degree (in fact, a measure of quality), between 0 and 1, to each value of a QoS parameter from users' preferences. Thus, for an application QoS parameter ρ_i, the utility function is $\upsilon_{\rho_i} : P_{\rho_i} \mapsto [0, 1]$ $(i = 1, 2, ..., n)$.

For building $\mathcal{Q}o\mathcal{S}$ from utility functions, let $\upsilon_{\rho_1}, \upsilon_{\rho_2}, ..., \upsilon_{\rho_n}$ be the utility functions and let $\omega_{\rho_1}, \omega_{\rho_2}, ..., \omega_{\rho_n}$ be the weights of the QoS parameters $\rho_1, \rho_2, ..., \rho_n$ of the application layer ($\sum_{i=1}^{n} \omega_{\rho_i} = 1$). For a QoS level $L_j =< \rho_{1_j}, \rho_{2_j}, ..., \rho_{n_j} >$, the quality degree function is $\mathcal{Q}o\mathcal{S}(< \rho_{1_j}, \rho_{2_j}, ..., \rho_{n_j} >) = \upsilon_{\rho_1}(\rho_{1_j}) \times \omega_{\rho_1} + \upsilon_{\rho_2}(\rho_{2_j}) \times \omega_{\rho_2} + ... + \upsilon_{\rho_n}(\rho_{n_j}) \times \omega_{\rho_n}$. For the example of Sect. 2, using this approach, we would have to perform $k \times (21 + 3 + 4)$ quality evaluations rather than $k \times 21 \times 3 \times 4$.

Methodology In order to check if the utility functions-based approach provides a $\mathcal{Q}o\mathcal{S}$ function similar to the one provided by exhaustive evaluations, we have performed a number of quality evaluations using a specially developed interface for that. Each test image (initially, only a talking head-type clip) was exhibited during ten seconds, in randomized order, and the total evaluation did not exceed 30 minutes, in order to avoid test subject's starvation. The interface generates log files containing additional information such as: test subject's name, test subject's skill, date, initial time, final time, sort of interface, and so on. Such data will permit further information related to result variations, not addressed in this paper. Five different test subjects have performed 600 evaluations. We have restricted the QoS parameters to video frame rate, whose domain is $F = \{10, 12, 15, 23.976, 24, 25, 29.97, 30\}$ and the DC accuracy ($D = \{8, 9, 10, 11\}$). Therefore,$P = \{< 10, 8 >, < 12, 8 >, ..., < 29.97,\ 11 >, < 30, 11 >\}$ ($|P| = 32$).

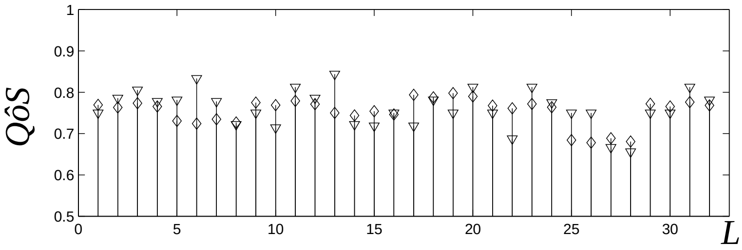

Fig. 1. Quality degrees: exhaustive tests × utility functions ($\omega_F = 0.7; \omega_D = 0.3$))

Results Graphic of Fig. 1 shows two resulting $\mathcal{QoS}$. Each point in x axis represents a QoS level L_i ($L_i \in P$); y axis represents $\mathcal{QoS}(L_i)$. Diamond-marked points are the quality degrees got from υ_F and υ_D ($\mathcal{QoS}(< F_j, D_j >) = 0.7 \times \upsilon_F(F_j) + 0.3 \times \upsilon_D(D_j)$); triangle-marked points are the quality degrees got from exhaustive evaluations. The difference between values, in the worst case, is around 17%. Note that $\mathcal{QoS}$ is simplified, not including B_i ($i = 1, 2, ..., n$).

4 Conclusion

In this paper, we described an approach for quantifying video quality by a function ($\mathcal{QoS}$) whose dimensions are bit rate, QoS level, and quality. Our preliminary results showed that we can reduce the quality quantification cost needed to build $\mathcal{QoS}$ by using several utility functions rather than exhaustive evaluations. However, the accuracy of this approach is strongly related to the correct weights assessment to QoS parameters. The current work include the implementation of a video distribution tool with a QoS controller based on using RTCP protocol [3] whose bit rate adjustment is done by using $\mathcal{QoS}$.

References

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